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(54) IN-PLANE SWITCHING ACTIVE MATRIX LIQUID CRYSTAL DISPLAY APPARATUS

(75) Inventor: Hideki Ito, Kanagawa (JP)

Correspondence Address:
MCGINN INTELLECTUAL PROPERTY LAW GROUP, PLLC
8321 OLD COURTHOUSE ROAD
SUITE 200
VIENNA, VA 22182-3817 (US)

(73) Assignee: NEC LCD TECHNOLOGIES, LTD., Kawasaki (JP)

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(57) ABSTRACT

In an in-plane switching active matrix LCD apparatus wherein a liquid crystal layer is sealed between a pair of transparent substrates and pectinate pixel electrodes and common electrodes are formed on the transparent substrates, a transparent continuous solid electrode that evenly covers the pixel is provided via a transparent insulating film to the bottom layers of the pixel electrodes and common electrodes, and this transparent continuous solid electrode is in an electrically floating state. Transmissivity can thereby be improved with a simple configuration.

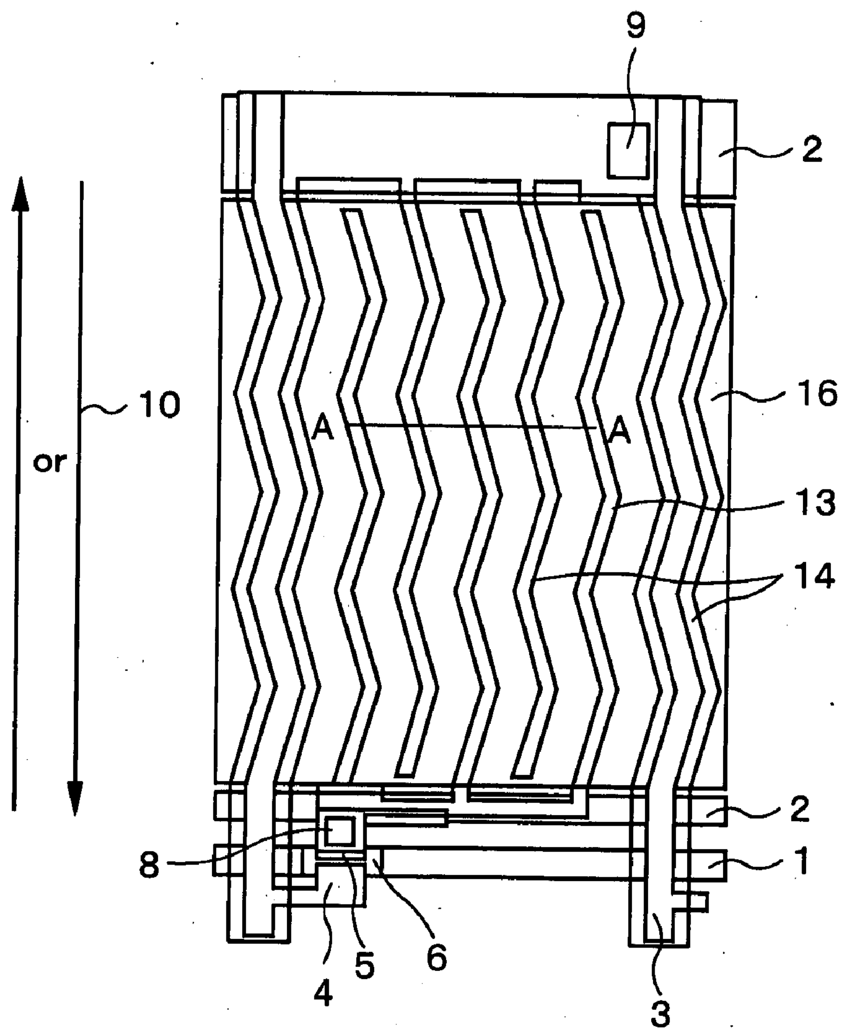


FIG. 1 (RELATED ART)

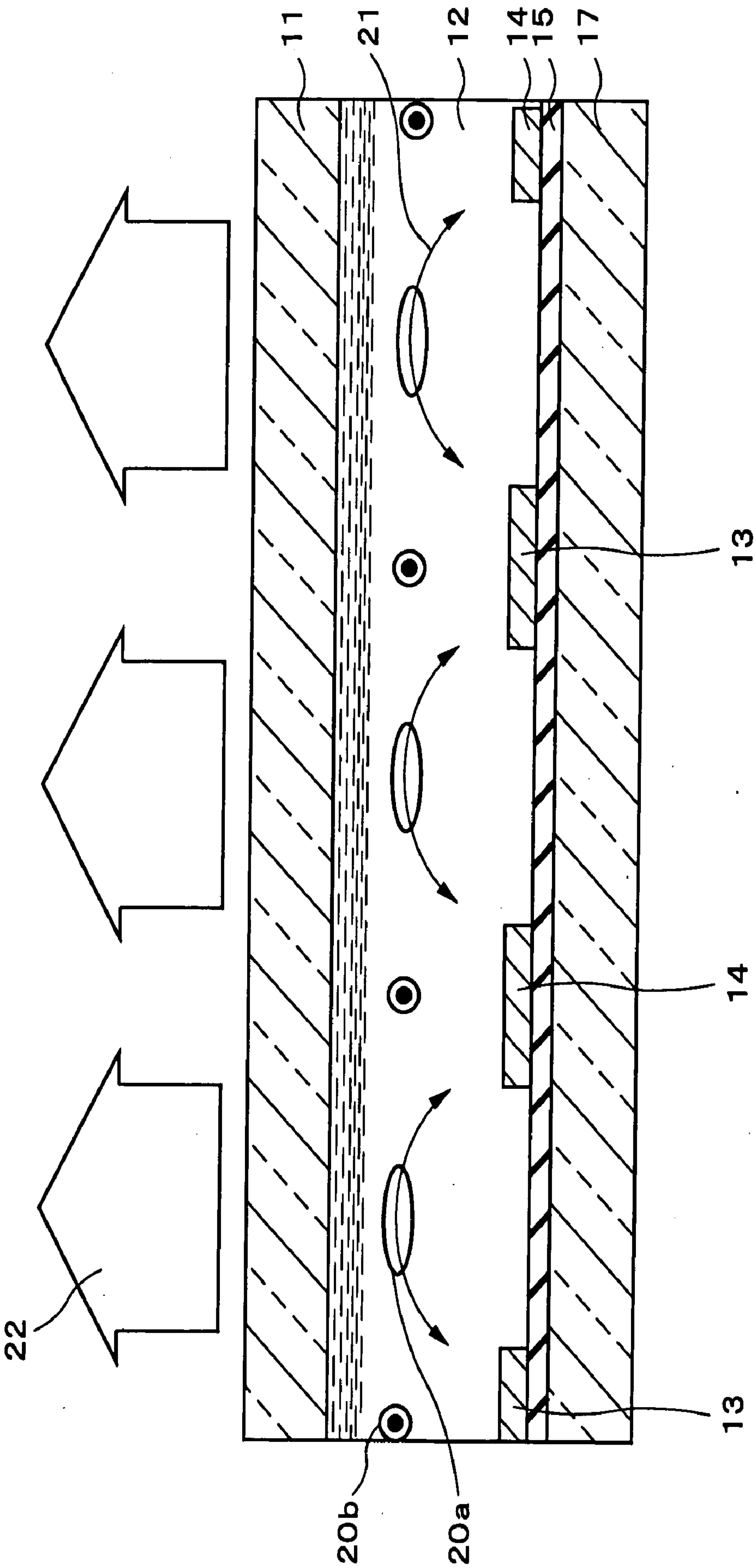


FIG. 2(RELATED ART)

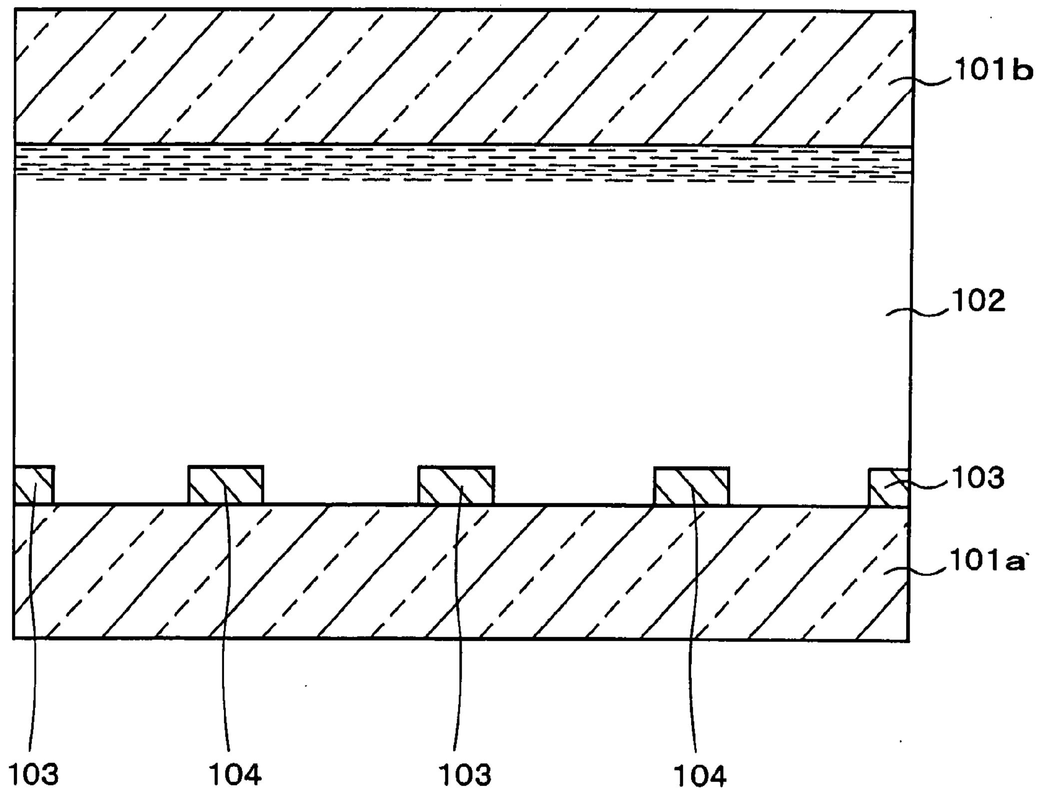


FIG. 3

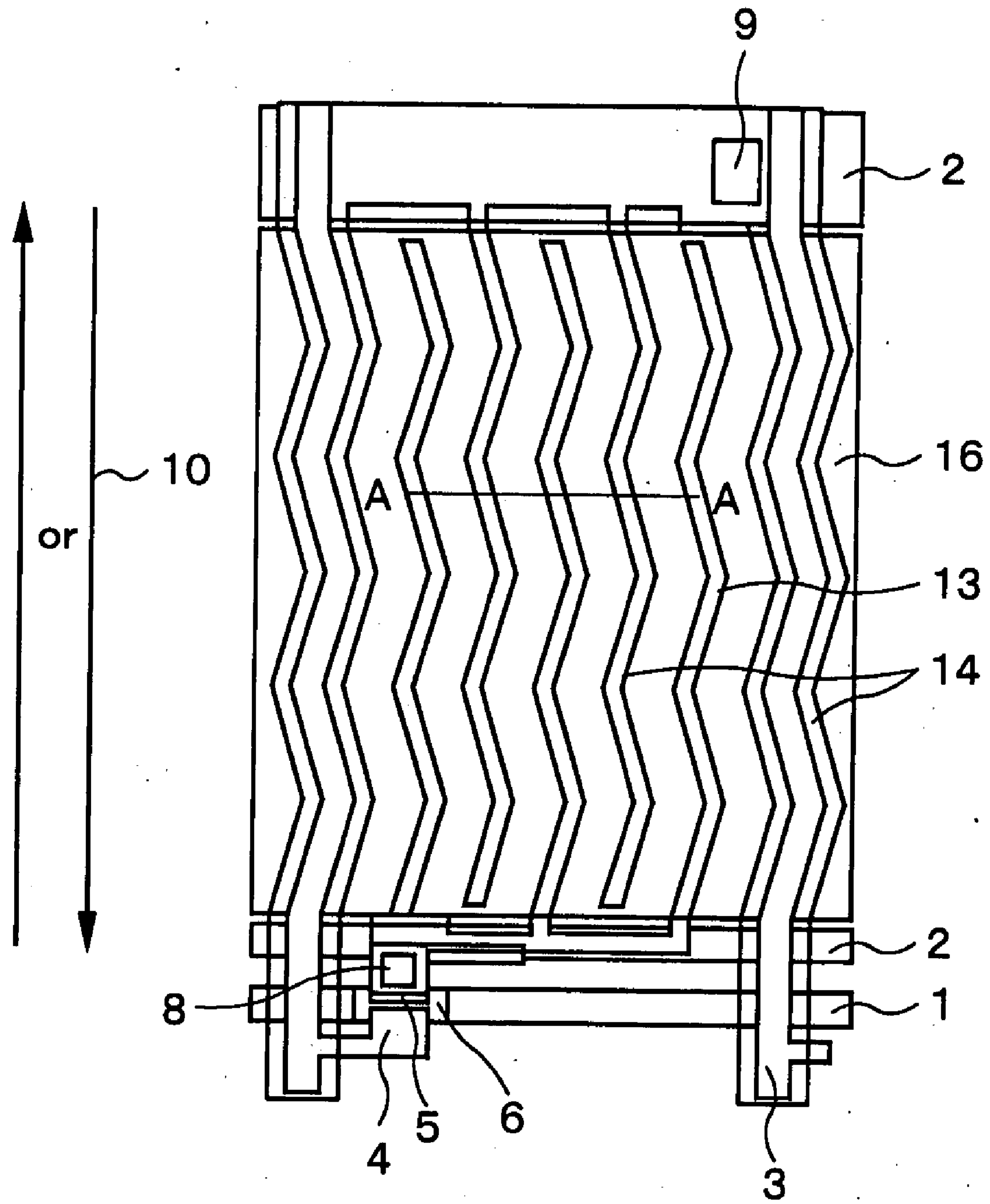


FIG. 4

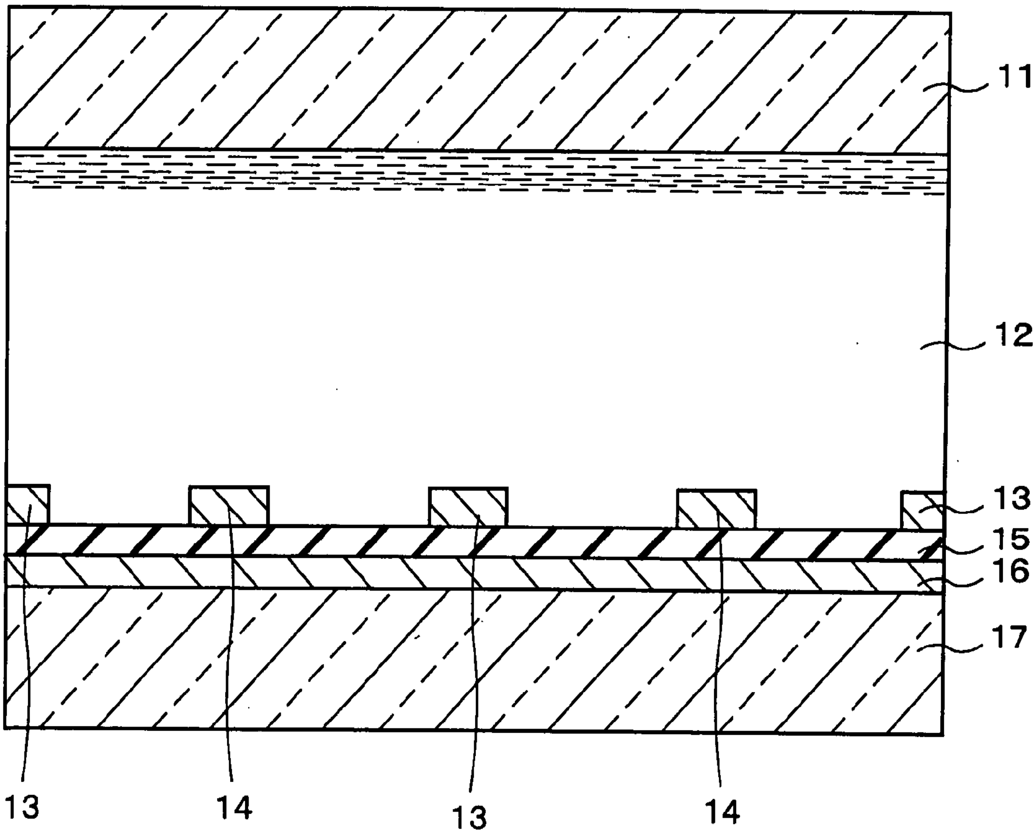
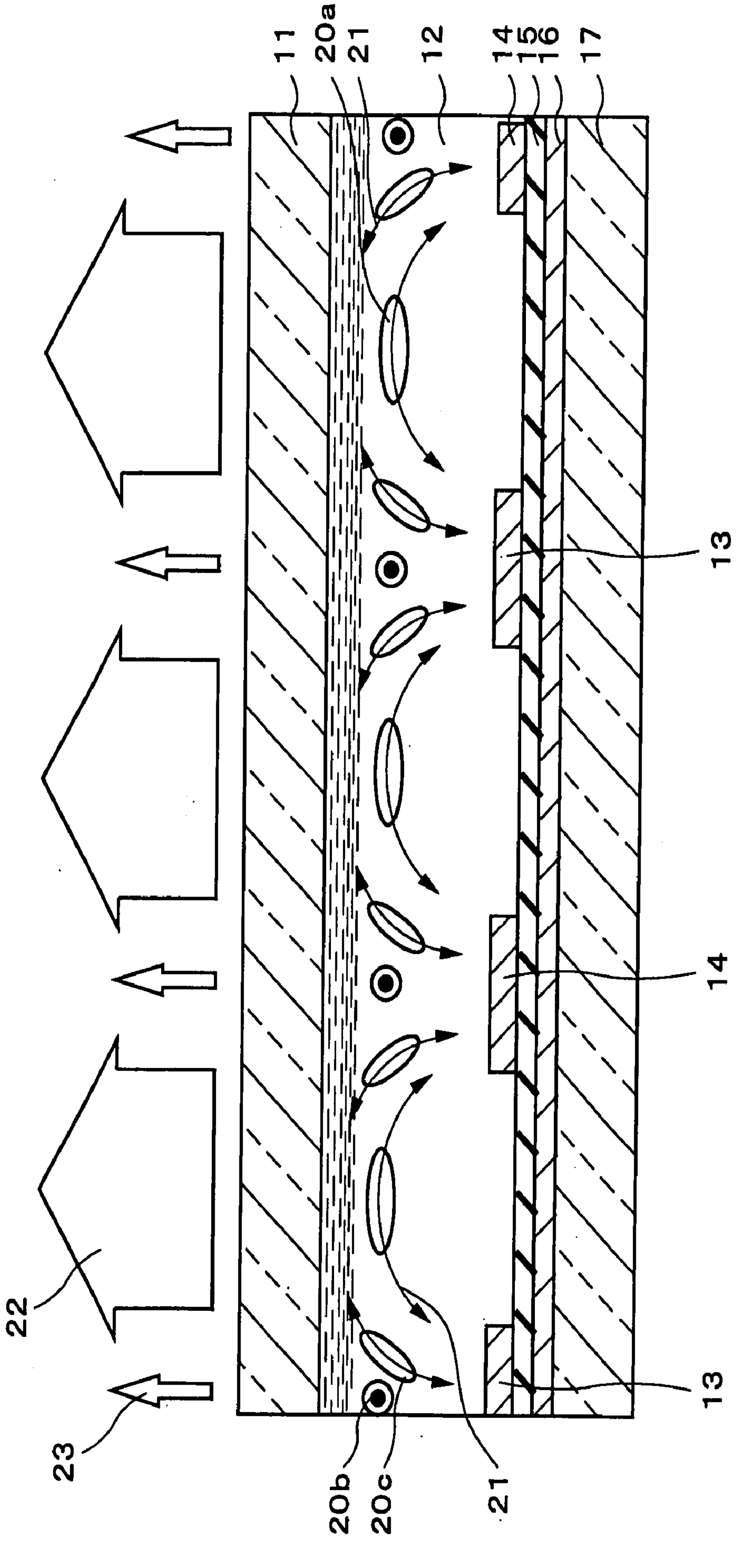


FIG. 5



IN-PLANE SWITCHING ACTIVE MATRIX LIQUID CRYSTAL DISPLAY APPARATUS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention The present invention relates to an in-plane switching active matrix liquid crystal display (LCD) apparatus that has improved transmissivity.

[0002] 2. Description of the Related Art

[0003] FIG. **1** is a cross-sectional view showing the operation of a conventional in-plane switching LCD apparatus, and FIG. **2** is a cross-sectional view schematically depicting a pixel of an in-plane switching LCD apparatus of the related art. In the related art in-plane switching LCD apparatus as shown in FIG. **2**, a liquid crystal layer **102** is provided between a pair of transparent substrates **101***a*, **101***b*, and pectinate pixel electrodes **103** and common electrodes **104** are disposed on the transparent substrate **101***a* in the aperture of the pixel.

[0004] When an image is displayed in the related art in-plane switching LCD apparatus thus configured, different voltages are applied between the pixel electrodes **103** and the common electrodes **104** to generate a horizontal electric field substantially parallel to the substrate surface between these electrodes, and this horizontal electric field causes the liquid crystal molecules between the electrodes to rotate within a plane substantially parallel to the substrate surface. Since images are displayed through rotation of the liquid crystal molecules within a plane parallel to the substrate surface, the viewing angle is not dependent on the rise angle of the liquid crystal molecules, which allows for a display with a wider viewing angle free of grayscale inversion.

[0005] The LCD apparatus disclosed in Japanese Laid-open Patent Application No. 2004-354407 (hereinafter Patent Document 1) is an example of a conventional in-plane switching LCD apparatus such as is described above. Patent Document 1 discloses an example of a configuration in which pixel electrodes and common electrodes are formed on one of a pair of opposing substrates, first continuous solid electrodes are provided via an insulating film on the bottom layers of the pixel electrodes and common electrodes on this substrate, and second continuous solid electrodes are formed on the liquid crystal layer side of the other substrate opposing the first substrate.

[0006] When an image is displayed in the conventional LCD apparatus having this configuration disclosed in Patent Document 1, voltages are applied between the pixel electrodes and the common electrodes, and the liquid crystal molecules are driven under the action of an electrical fi eld substantially parallel to the substrate surface. In the initial stage of the image non-display state, voltage is applied between the first continuous solid electrodes and the common and pixel electrodes, as well as between the second continuous solid electrodes and the common and pixel electrodes without being applied between the pixel electrodes and the common electrodes. This generates a vertical electric field and raises the liquid crystal molecules, displaying a black screen. Following the initial stage of the image non-display state, the electrodes are brought to the same electric potential, whereby the pixel interiors lose their electric field, the raised liquid crystal molecules revert to their initial alignments, and the black display remains. Generating a vertical electric field in the initial stage of the image non-display state makes it possible to reduce rise-and-fall response time, to inhibit blurring of moving images, and to provide high-quality moving images.

[0007] However, the conventional technology described above has the following problems.

[0008] In a conventional in-plane switching active matrix LCD apparatus, since pectinate electrodes are formed inside the pixels on one of the substrates, the apertures are inevitably smaller, causing transmissivity to be reduced. In particular, there have been problems with low transmissivity in LCD apparatuses because the liquid crystal molecules on the electrodes cannot be driven.

SUMMARY OF THE INVENTION

[0009] An object of the present invention is to provide an in-plane switching active matrix LCD apparatus wherein transmissivity is improved by a simple configuration.

[0010] The in-plane switching active matrix LCD apparatus according to the present invention has a first substrate, a second substrate facing the first substrate, a liquid crystal layer provided between the first and second substrates, data lines and gate lines that are formed on the first substrate and that intersect in matrix fashion, a thin-film transistor formed on the first substrate in each pixel area partitioned by the data lines and gate lines, a common line formed on the substrate and used to apply a reference potential across the pixels, pixel electrodes and common electrodes formed in the pixel areas on the first substrate and used to generate a horizontal electric field parallel to the substrate surfaces, and a transparent continuous solid electrode formed via a transparent insulating layer on the bottom layers of the pixel electrodes and common electrodes on the first substrate.

[0011] The transparent continuous solid electrode is preferably in an electrically floating state.

[0012] The transparent continuous solid electrode can be formed uniformly so as to cover the apertures of the pixels.

[0013] The pixel electrodes and the common electrodes can be made from transparent electrodes.

[0014] The pixel electrodes and the common electrodes may be formed in pectinate or comb-like shapes (hereinafter called as pectinate shapes) that mesh with each other.

[0015] The pixel electrodes and the common electrodes may be formed on the same layer.

[0016] The transparent continuous solid electrode may be formed on the same layer as the gate lines and the common line. Alternatively, the transparent continuous solid electrode may be formed between the gate lines and common line via a transparent insulating layer.

[0017] According to the present invention, in an in-plane switching active matrix LCD apparatus, pectinate electrodes for generating a horizontal electric field are formed on a substrate, and a transparent continuous solid electrode is provided via a transparent insulating layer underneath the electrodes on the substrate, whereby a horizontal electric field is applied to a liquid crystal layer on the pectinate electrodes, the horizontal electric field varies the alignment of liquid crystal molecules above the pectinate electrodes, and the transmissivity above the pectinate electrodes is improved. Thus, the transmissivity of the LCD apparatus can be improved without changing the width and/or spaces between the pectinate electrodes. The contrast also improves proportionate to the improvement in transmissivity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. **1** is a cross-sectional view showing the operation of a related art in-plane switching LCD apparatus;

[0019] FIG. **2** is a cross-sectional view schematically depicting a pixel of a related art in-plane switching LCD apparatus;

[0020] FIG. **3** is a plan view showing a pixel of the in-plane switching active matrix LCD apparatus according to an exemplary embodiment of the present invention;

[0021] FIG. **4** is a cross-sectional view along the line A-A in FIG. **3**; and

[0022] FIG. **5** is a cross-sectional view showing the operation of an exemplary embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] In view of above-noted problems, an object of the present invention is to improve transmissivity by focusing on the alignment of liquid crystal molecules and by improving the liquid-crystal molecular alignment when an image is displayed. In Patent Document 1, continuous solid electrodes are formed on the bottom layers of the pixel electrodes and the common electrodes in the same manner as in the present invention. However, continuous solid electrodes are also formed on the opposing substrate, and the purpose of this arrangement is to quickly produce a black display in the initial stage of the image non-display state. In the present invention, the continuous solid electrodes are preferably kept in an electrically floating state. By contrast, in Patent Document 1, the continuous solid electrodes are not kept in an electrically floating state. Specifically, if the continuous solid electrodes are brought to an electrically floating state in the configuration in Patent Document 1, the desired black display in this document is not achieved, and transmissivity is reduced by the continuous solid electrodes formed on the opposing substrate.

[0024] Exemplary embodiments of the present invention are described in detail below with reference to the attached diagrams. FIG. **3** is a plan view showing a pixel of the in-plane switching active matrix LCD apparatus according to an exemplary embodiment of the present invention, and FIG. **4** is a cross-sectional view along the line A-A in FIG. **3**.

[0025] The LCD apparatus of the exemplary embodiment operates on an active matrix principle. The display area of the liquid crystal panel is composed of multiple pixels partitioned by multiple gate lines and data lines arranged in matrix-fashion, and a thin film transistor (TFT), which is a switching element, is formed on each pixel. A gate line **1** and a common line **2** are formed on a transparent substrate **17** and are disposed parallel to each other, as shown in FIGS. **3** and **4**. A transparent continuous solid electrode **16**, which is transparent and electroconductive, is formed on the transparent substrate **17** on which the gate line **1** and common line **2** are formed, and the transparent continuous solid electrode **16** has a square shape so as to uniformly cover the aperture of the pixel. The transparent continuous solid electrode **16** is electrically independent in a so-called floating state, and is formed so as to be electrically insulated from the gate line **1** and the common line **2**. The transparent continuous solid electrode **16** is formed from, e.g., ITO (indium tin oxide) or another such transparent electroconductive material.

[0026] A gate-insulating film (not shown) is stacked over the gate line **1**, the common line **2**, and the transparent continuous solid electrode **16**. The configuration is otherwise the same as a typical in-plane switching active matrix LCD apparatus. Specifically, an a—Si (amorphous silicon) layer **6** is formed at a specific location on the gate line **1** via a gate-insulating film, and a source electrode **4** and drain electrode **5** are formed so as to cover the a—Si (amorphous silicon) layer **6** from the two lateral ends of the gate line **1**. A data line **3** is formed so as to be connected with the source electrode **4** and to extend in a direction orthogonal to the gate line **1**. Thus, a thin-film transistor is formed in the vicinity of the points of intersection between the gate lines **1** and the data lines **3** of each pixel. Furthermore, a transparent insulating film **15** is stacked so as to cover the data line **3**, the source electrode **4**, the drain electrode **5**, and the gate-insulating film. Two layers, referred to as a semiconductor layer and a contact layer, are typically stacked on the a—Si layer in order to improve the characteristics of the thin-film transistor.

[0027] Pectinate pixel electrodes **13** and common electrodes **14** are formed on the pixel area on the transparent insulating film **15** so as to mesh with each other. These pixel electrodes **13** and common electrodes **14** are formed from ITO or another such transparent electroconductive material. In one example of the pectinate shape, a series of "V" shapes is aligned in the extending direction of the comb teeth as shown in FIG. **3**, and except for the curved parts, the pixel electrodes **13** and the common electrodes **14** are arranged parallel to each other. The shapes of the pixel electrodes **13** and common electrodes **14** are not limited to the shapes in the present embodiment, and other possibilities include single "V" shapes, pectinate electrodes formed in straight lines, and any other shapes as long as the electrodes generate a horizontal electric field. A horizontal electric field is generated by applying different voltages between the pectinate pixel electrodes **13** and common electrodes **14**. The teeth portions of the pectinate pixel electrodes **13** and common electrodes **14** are disposed in the aperture of the pixel, and are superposed over the transparent continuous solid electrode **16** in a plan view. A contact hole **9** is provided so that the common electrodes **14** are electrically conductive with the common line **2**, and a contact hole **8** is provided so that the pixel electrodes **13** are electrically conductive with the drain electrode **5**.

[0028] An alignment film (not shown) for aligning the liquid crystal molecules is formed on the transparent substrate **17** on which the pixel electrodes **13** and common electrodes **14** are thus formed, and the surface of this alignment film is subjecting to rubbing. A transparent substrate **11** is disposed so as to face the transparent substrate **17**, and a color filter (not shown) is formed on the surface of the transparent substrate **11** that faces the transparent substrate **17**. Furthermore, an alignment film (not shown) for aligning the liquid crystal molecules is formed on the outermost surface of the transparent substrate **11** that faces the transparent substrate **17**, and the surface of this alignment film is subjected to rubbing. The rubbing for the alignment films provided to this pair of transparent substrates **11** and **17** is typically performed in a direction that produces a homogeneous alignment in the liquid crystal molecules. The rubbing direction **10** is perpendicular to the gate line **1** and parallel to the extending direction of the pixel electrodes **13** and common electrodes **14**, as shown in FIG. **3**. In cases in which pectinate electrodes extending in straight lines are used as the pixel electrodes **13** and common electrodes **14**, the rubbing direction **10** must be inclined, for example, by several to several dozen degrees in relation to the extending direction of the comb teeth, and a pretwist angle that is not zero must be provided.

[0029] The LCD apparatus of the present embodiment is configured with liquid crystal filled in between the transparent substrates **11** and **17** provided with a TFT and a color filter, respectively, and a liquid crystal layer **12** is sealed in between the substrates as shown in FIG. **4**. Polarizing plates (not shown) are provided to both transparent substrates **11** and **17** on the sides opposite those in contact with the liquid crystal layer **12**, and this pair of polarizing plates is arranged to form a crossed Nichol prism. The LCD apparatus of the present embodiment also has a light source device (not shown), and light emitted by the light source device passes through the transparent substrate **17**, whereby images are displayed.

[0030] In the present embodiment, the transparent continuous solid electrode **16** is formed on the same layer as the gate line **1** and the common line **2**, but the transparent continuous solid electrode **16** may also be formed between the gate line **1** and the common line **2** via a transparent insulating film. For example, the transparent continuous solid electrode **16** may be formed on the transparent substrate **17**, a transparent insulating film may be stacked thereon so as to cover the transparent continuous solid electrode **16**, and the gate line **1** and common line **2** may be formed on this transparent insulating film, after which a gate-insulating film may be formed.

[0031] Next, the operation of the present embodiment will be described with reference to FIGS. **3** and **1**. The liquid crystal molecules herein are, e.g., liquid crystal molecules having positive dielectric anisotropy, i.e., liquid crystal molecules typically referred to as positive. As shown in FIG. **3**, when voltage is not applied between the pixel electrodes **13** and the common electrodes **14**, the initial alignment of the liquid crystal molecules is in the same direction as the rubbing direction **10**, the major axis direction of the liquid crystal molecules coincides with the direction of axial absorption of the polarizing plates, and the two polarizing plates are arranged so that the axes of absorption are orthogonal to each other. Therefore, light transmissivity is extremely low. When different voltages are applied between the pixel electrodes **13** and common electrodes **14**, an electric field is generated substantially parallel to the substrate surfaces and in the shortest direction between the pixel electrodes **13** and common electrodes **14**. This electric field is a so-called horizontal electric field. The liquid crystal molecules between the electrodes are driven by this horizontal electric field to rotate within a plane parallel to the substrates, and the alignment of the liquid crystal molecules changes so that the major axes of the liquid crystal molecules are parallel to the horizontal electric field. Therefore, transmissivity is high. Since an example was given in which the shapes of the pixel electrodes **13** and common electrodes **14** are a series of "V" shapes, the direction of the horizontal electric field alternates when crossing the V-shaped curved parts. Therefore, the liquid crystal molecules rotate in the opposite directions on the two sides of the V-shaped curved parts, and the major axes of the liquid crystal molecules become parallel to the direction of the horizontal electric field.

[0032] FIG. **5** is a cross-sectional view showing the operation of the present embodiment when voltage is applied between the pixel electrodes **13** and common electrodes **14**. Structural elements in FIG. **5** that are similar to those in FIG. **4** are denoted by the same numerical symbols and are not described in detail. As shown in FIG. **5**, a horizontal electric field substantially parallel to the substrate surfaces is generated in the vicinity of the centers between the pixel electrodes **13** and common electrodes **14**, and the major axes of liquid crystal molecules **20***a* between the electrodes are also substantially parallel to the direction **21** of the horizontal electric field, and are parallel to the substrate surfaces. Therefore, transmissivity is improve d between the pixel electrodes **13** and common electrodes **14**, and transmitted light **22** is generated between the pectinate electrodes. Applying different voltages between the pixel electrodes **13** and common electrodes **14** provides the transparent continuous solid electrode **16** with electric potential and generates a horizontal electric field that has vertical components between the transparent continuous solid electrode **16** and the pixel electrodes **13** and common electrodes **14**. This horizontal electric field with vertical components also penetrates into the liquid crystal layer **12** and changes the alignment of the liquid crystal molecules so as to increase the brightness of the LCD apparatus. Specifically, above the pixel electrodes **13** and common electrodes **14**, this horizontal electric field with vertical components also has electric field components in the horizontal direction parallel to the substrate surfaces. Therefore, the electric field having vertical and horizontal components causes the liquid crystal molecules **20***c* to rise and to rotate within a plane parallel to the substrate surfaces, and the liquid crystal molecules **20***c* become inclined in relation to the substrate surfaces. Therefore, the transmissivity above the pixel electrodes **13** and common electrodes **14** is improved, and transmitted light **23** above the pectinate electrodes is generated above the pixel electrodes **13** and common electrodes **14**.

[0033] Thus, in the present embodiment, an electric potential is imparted to the transparent continuous solid electrode **16**, whereby the alignment of the liquid crystal molecules above the pixel electrodes **13** and common electrodes **14** is changed and transmissivity is improved. Such an improvement in transmissivity above the electrodes is not achieved in conventional in-plane switching LCD apparatuses. FIG. **1** is a cross-sectional view showing the operation of a conventional in-plane switching LCD apparatus. As shown in FIG. **1**, a transparent continuous solid electrode is not provided as in the present embodiment, and the electric field above the pixel electrodes **13** and common electrodes **14** is therefore not horizontal. Accordingly, the liquid crystal molecules cannot be sufficiently rotated and transmissivity is low. Therefore, transmitted light is generated primarily between the pixel electrodes **13** and common electrodes **14**.

Structural elements in FIG. **1** that are similar to those in FIG. **5** are denoted by the same numerical symbols and are not described in detail.

[0034] The transparent continuous solid electrode **16** is in an electrically floating state, but a normally black in-plane switching LCD apparatus may be structured so that a suitable voltage is applied to the transparent continuous solid electrode **16** when an electric field is applied to the liquid crystal layer to light the screen, or that the transparent continuous solid electrode **16** has the same electric potential as the common electrodes **14**.

[0035] Next, the effects of the present embodiment will be described. In the in-plane switching active matrix LCD apparatus according to the present embodiment, a transparent continuous solid electrode **16** is formed via a transparent insulating film **15** below the pectinate pixel electrodes **13** and common electrodes **14** formed in a pixel, whereby the transparent continuous solid electrode **16** is provided with an electric potential while the liquid crystal is driven, a horizontal electric field having vertical components generated between the transparent continuous solid electrode **16** and the pixel electrodes **13** and common electrodes **14** also penetrates into the liquid crystal layer **12**, and the alignment of the liquid crystal molecules is varied so as to increase the brightness of the LCD apparatus. Specifically, a simple structure is provided in which transparent electrodes are arranged in continuous solid fashion in the pixel apertures, whereby the liquid crystal layer **12** can be subjected to an electric field that provides higher transmissivity than the horizontal electric field in the conventional structure, and the transmissivity can be improved without changing the width and/or spaces between the pectinate electrodes. The contrast also improves proportionate to the improvement in transmissivity.

[0036] Various modifications can be made to the present invention within the technical scope based on the claims, and the technical scope of the present invention is not in any way limited by the embodiments of the present invention.

What is claimed is:

1. An in-plane switching active matrix liquid crystal display apparatus, comprising:

a first substrate;

a second substrate facing the first substrate;

a liquid crystal layer provided between the first and second substrates; data lines and gate lines that are formed on the first substrate and that intersect in matrix fashion;

a thin-film transistor formed on the first substrate in each pixel area partitioned by the data lines and gate lines;

a common line formed on the substrate and used to apply a reference potential across the pixels;

pixel electrodes and common electrodes formed in the pixel areas on the first substrate and used to generate a horizontal electric field parallel to the substrate surfaces; and

a transparent continuous solid electrode formed via a transparent insulating layer on the bottom layers of the pixel electrodes and common electrodes on the first substrate.

2. The in-plane switching active matrix liquid crystal display apparatus according to claim 1, wherein the transparent continuous solid electrode is in an electrically floating state.

3. The in-plane switching active matrix liquid crystal display apparatus according to claim 1, wherein the transparent continuous solid electrode is formed uniformly so as to cover the apertures of the pixels.

4. The in-plane switching active matrix liquid crystal display apparatus according to claim 2, wherein the transparent continuous solid electrode is formed uniformly so as to cover the apertures of the pixels.

5. The in-plane switching active matrix liquid crystal display apparatus according to claim 1, wherein the pixel electrodes and the common electrodes are transparent electrodes.

6. The in-plane switching active matrix liquid crystal display apparatus according to claim 2, wherein the pixel electrodes and the common electrodes are transparent electrodes.

7. The in-plane switching active matrix liquid crystal display apparatus according to claim 1, wherein the pixel electrodes and the common electrodes are formed in pectinate shapes that mesh with each other.

8. The in-plane switching active matrix liquid crystal display apparatus according to claim 2, wherein the pixel electrodes and the common electrodes are formed in pectinate shapes that mesh with each other.

9. The in-plane switching active matrix liquid crystal display apparatus according to claim 1, wherein the pixel electrodes and the common electrodes are formed on the same layer.

10. The in-plane switching active matrix liquid crystal display apparatus according to claim 2, wherein the pixel electrodes and the common electrodes are formed on the same layer.

11. The in-plane switching active matrix liquid crystal display apparatus according to claim 1, wherein the transparent continuous solid electrode is formed on the same layer as the gate lines and the common line.

12. The in-plane switching active matrix liquid crystal display apparatus according to claim 2, wherein the transparent continuous solid electrode is formed on the same layer as the gate lines and the common line.

13. The in-plane switching active matrix liquid crystal display apparatus according to claim 1, wherein the transparent continuous solid electrode is formed between the gate lines and common line via a transparent insulating layer.

14. The in-plane switching active matrix liquid crystal display apparatus according to claim 2, wherein the transparent continuous solid electrode is formed between the gate lines and common line via a transparent insulating layer.

* * * * *

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申请(专利权)人(译)	NEC液晶技术有限公司.		
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摘要(译)

在面内切换有源矩阵LCD装置中，液晶层密封在一对透明基板之间，梳状像素电极和公共电极形成在透明基板上，通过均匀覆盖像素的透明连续固体电极通过透明绝缘膜到像素电极和公共电极的底层，并且该透明连续固体电极处于电浮置状态。由此可以通过简单的配置改善透射率。